Process-Oriented Diagnostics to Inform Model Development

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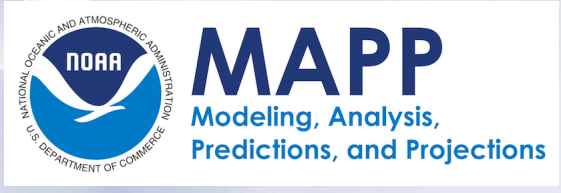
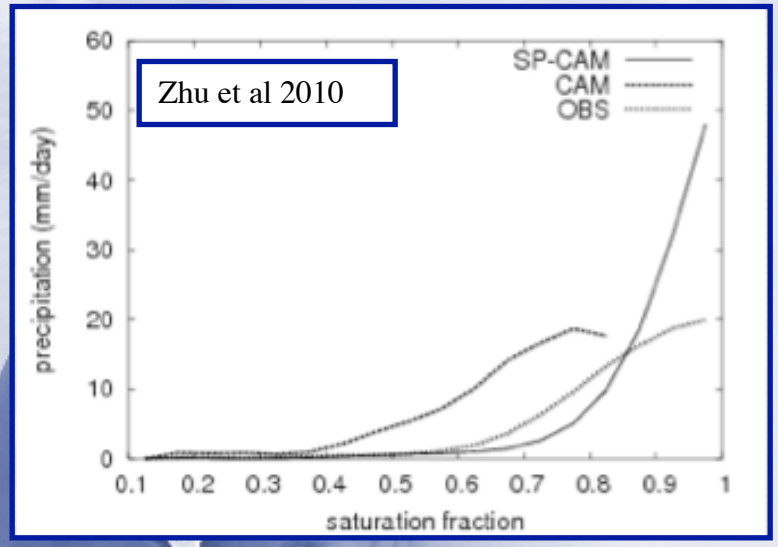
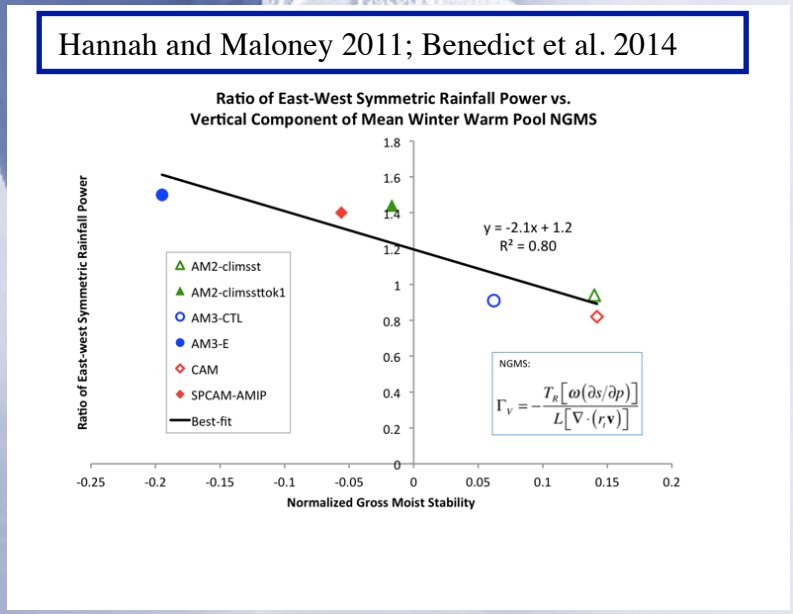
Sponsors: NOAA MAPP, NSF Climate and Large-Scale Dynamics

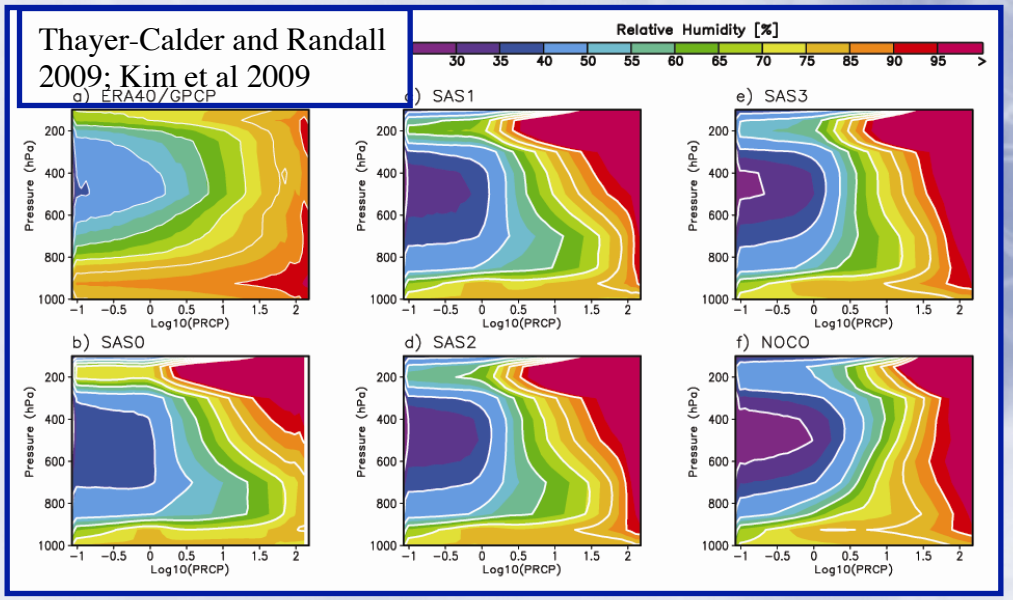


WGNE MJO Task Force Subproject: Process-Oriented Diagnostics



- Exploring Diagnostics/Metrics that provide more insight into why a model may have a good/poor MJO
- Facilitate improvements in convective and other physical parameterizations relevant to the MJO





CMIP5 TASK FORCE

Applications of Task Force members' funded projects

Projections of North American climate informing applications (e.g., National Climate Assessment)

Process-based model evaluation metrics geared toward informing model development

- To-be-delivered NCA is based on CMIP3 results
- Task Force responded to a series of questions on CMIP3/CMIP5 differences, changes in North American climate
- Working on a NOAA technical report and publication detailing findings; a contribution to the assessment process

Process-based model evaluation metrics geared toward informing the user community and stakeholders

- Process- as opposed to variable-oriented evaluation of model biases
  - Extension to modeling center development efforts

MAPP
Modeling, Analysis, Predictions, and Projections

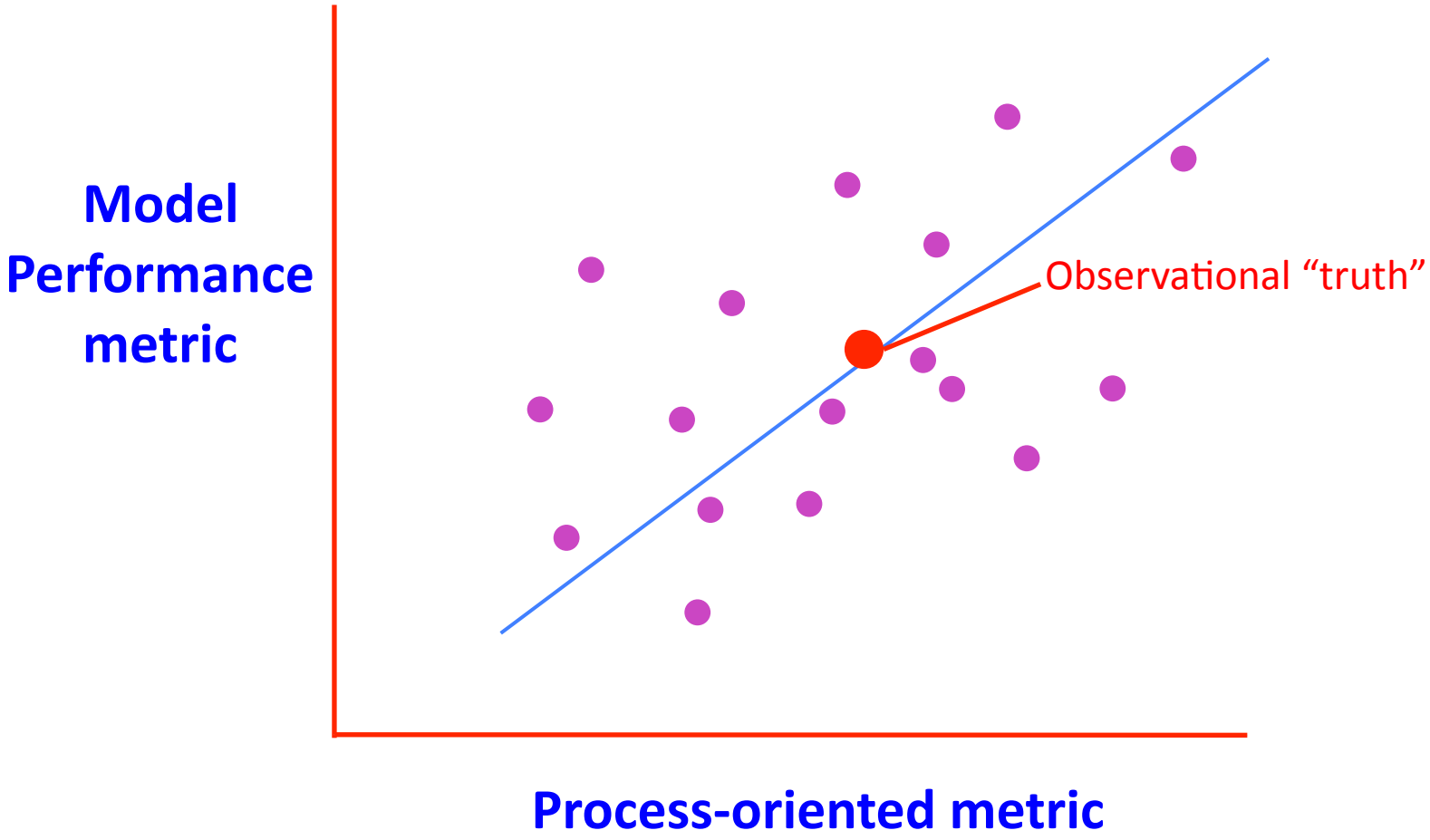
www.cpo.noaa.gov/MAPP/CMIP5TF

NOAA MAPP CMIP5 Task Force Process-Oriented Diagnostics Efforts

MAPP
Modeling, Analysis, Predictions, and Projections

- A goal of the TF is to evaluate simulations of the 20th century climate and the uncertainties in long-term predictions and projection of twenty-first century climate over North America
- Develop process-oriented model diagnostics to understand why some models produce a good simulation of NA climate, and why others do not.
- Go beyond a simple diagnosis of whether models can or cannot simulate a particular phenomenon, and provide physical understanding (including why improved simulation of some phenomena degrades other aspects of climate).
- Provide guidance to model development community (and the applications community)

Idealization of the Concept



Other diagnostic frameworks are obviously possible

Column-Integrated MSE (h) Budget Diagnostics for the MJO

$$\langle \partial_t h \rangle = -\langle \mathbf{v} \cdot \nabla h \rangle - \langle \omega \partial_p h \rangle + \langle Q_R \rangle + LHF + SHF$$

- Vertical Gross Moist Stability: $-\langle \omega \partial_p h \rangle = \Gamma_V C$ $\quad \Gamma_v = \dfrac{-\langle \omega \partial_p h \rangle}{C}$

  Dep . on vertical heating, MSE profiles

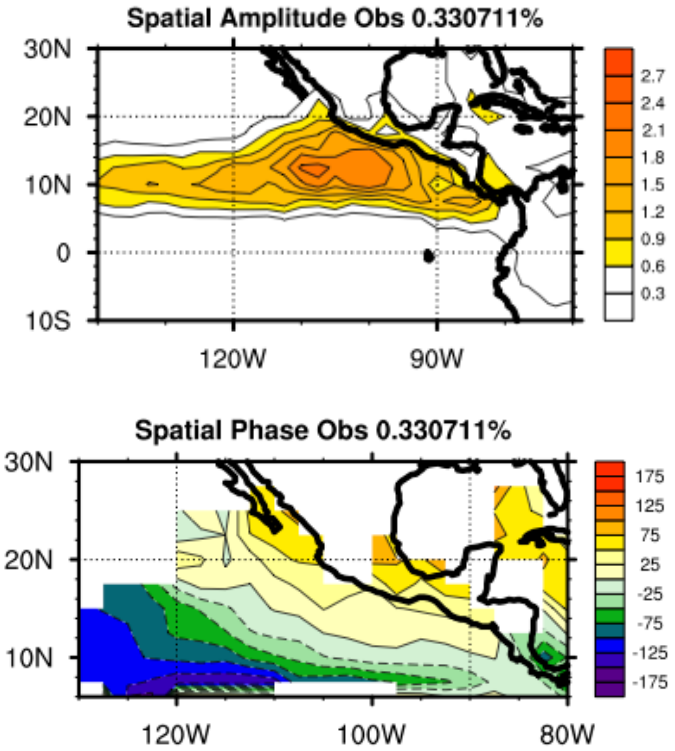
- Effective Gross Moist Stability: $-\langle \omega \partial_p h \rangle + \langle Q_R \rangle = \Gamma_{eff} C$

- Horizontal Gross Moist Stability $-\langle \mathbf{v} \cdot \nabla h \rangle = \Gamma_H C$ $\quad \Gamma_h = \dfrac{-\langle \mathbf{v} \cdot \nabla h \rangle}{C}$

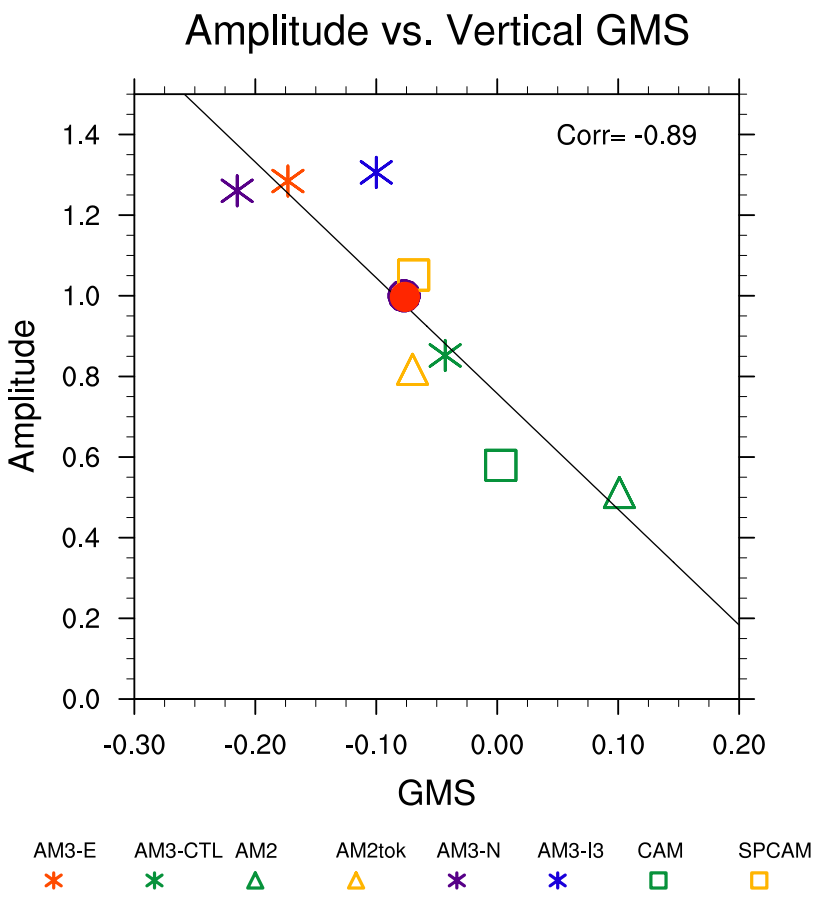
- C is a measure of convective activity, and might be: vertically integrated moisture convergence, dry static energy export, mass flux, precipitation, etc.
- Γ_H and Γ_V provide measures of how efficiently horizontal and vertical advection discharge m from the column.

Vertical Component of GMS (Γ_v) Versus Boreal Summer East Pacific Leading Mode Amplitude

Leading 30-90d precipitation complex EOF mode



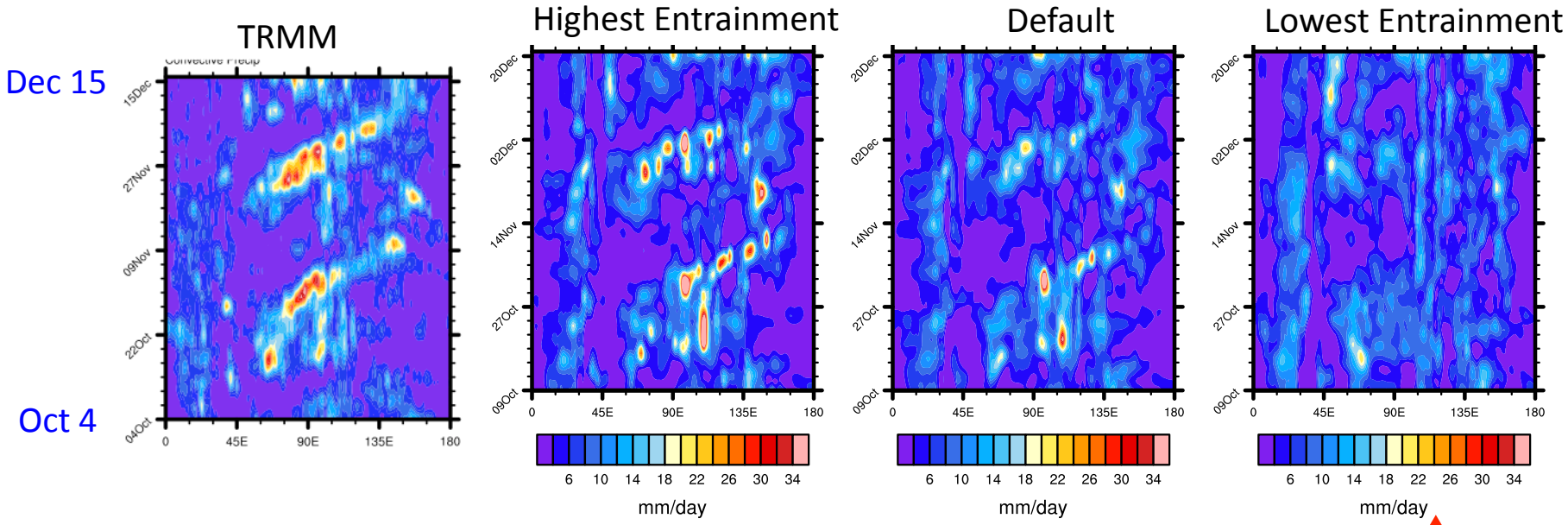
Maloney et al. (2014)



- Models have significant spread of leading mode amplitudes
- VGMS lower in models with stronger variability.

NCAR CAM5 DYNAMO Hindcasts at One-Week Lead Time

Hannah and Maloney (2014)



Lower entrainment leads to less coherent precipitation variability and weaker MJO amplitude

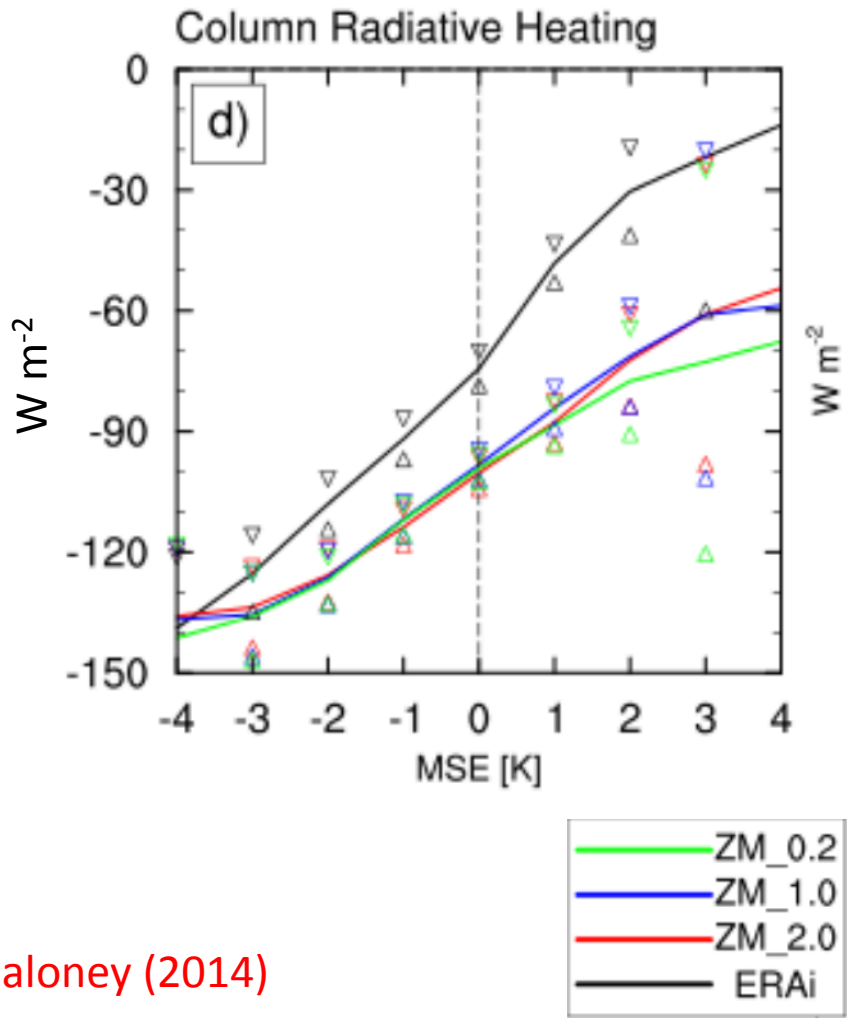
Stronger MSE anomalies maintained in the higher entrainment runs

Simulation	Entrainment [km^{-1}]
ZM_0.2	0.2
ZM_1.0	1.0
ZM_2.0	2.0

Radiative Feedbacks in CAM5 Appear Too Weak

(Well, at Least Weaker than ERA-i)

- Radiative feedbacks in CAM5 are too weak in all simulations (compared to ERA-I at least).
- Too low of GMS may be compensating for this too weak radiative feedback in the high entrainment cases to produce a reasonable MJO
- Similar to results recently found by Daehyun Kim



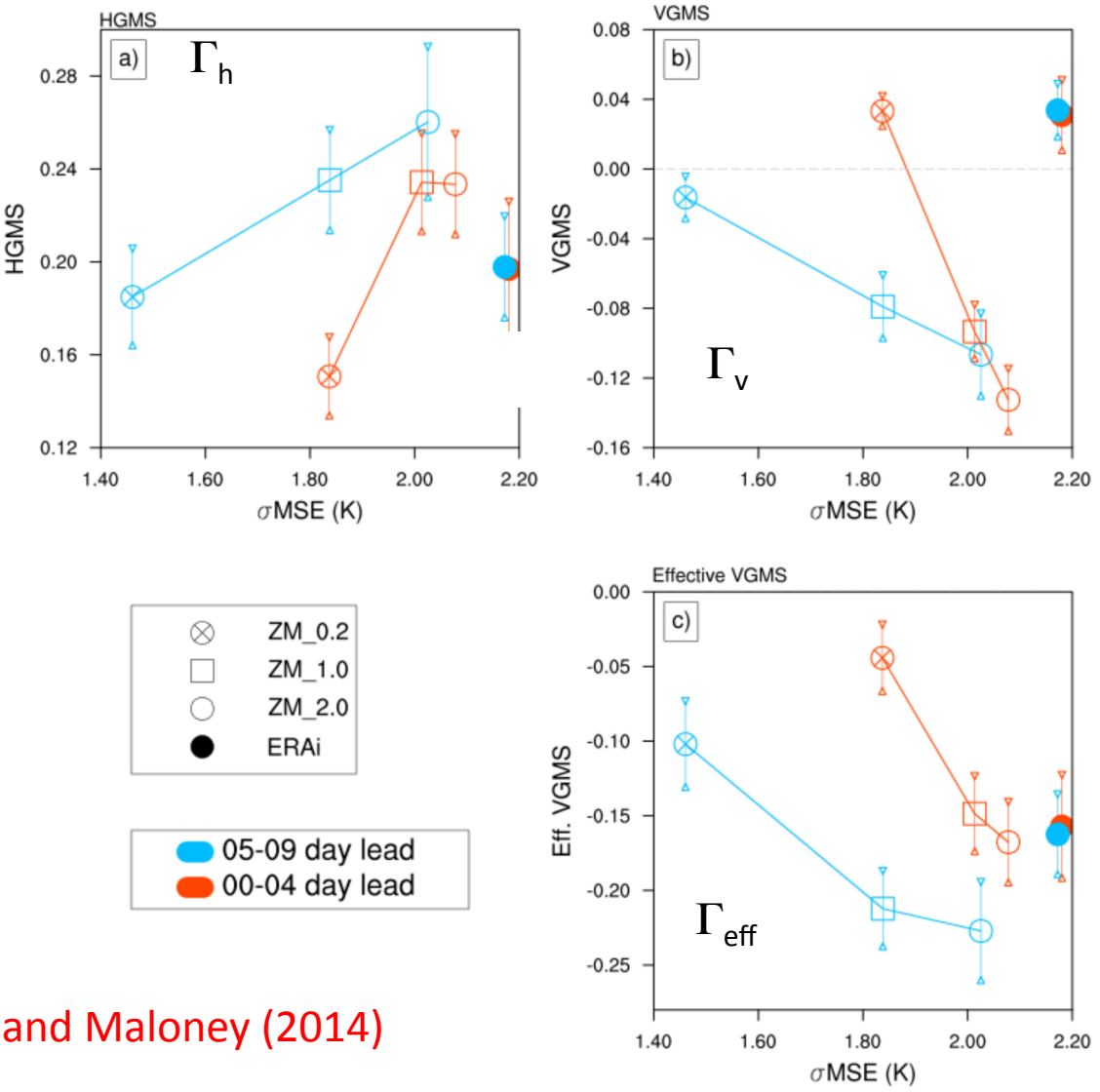
Hannah and Maloney (2014)

Mean GMS vs. Standard Deviation of MSE

The mean VGMS over the equatorial Indian Ocean shows a systematic reduction as entrainment is enhanced, which follows the improvement of the MJO amplitude

However, the value of VGMS is unrealistic.

Effective VGMS however that includes radiative feedbacks (and surface fluxes) is commensurate between models and obs.



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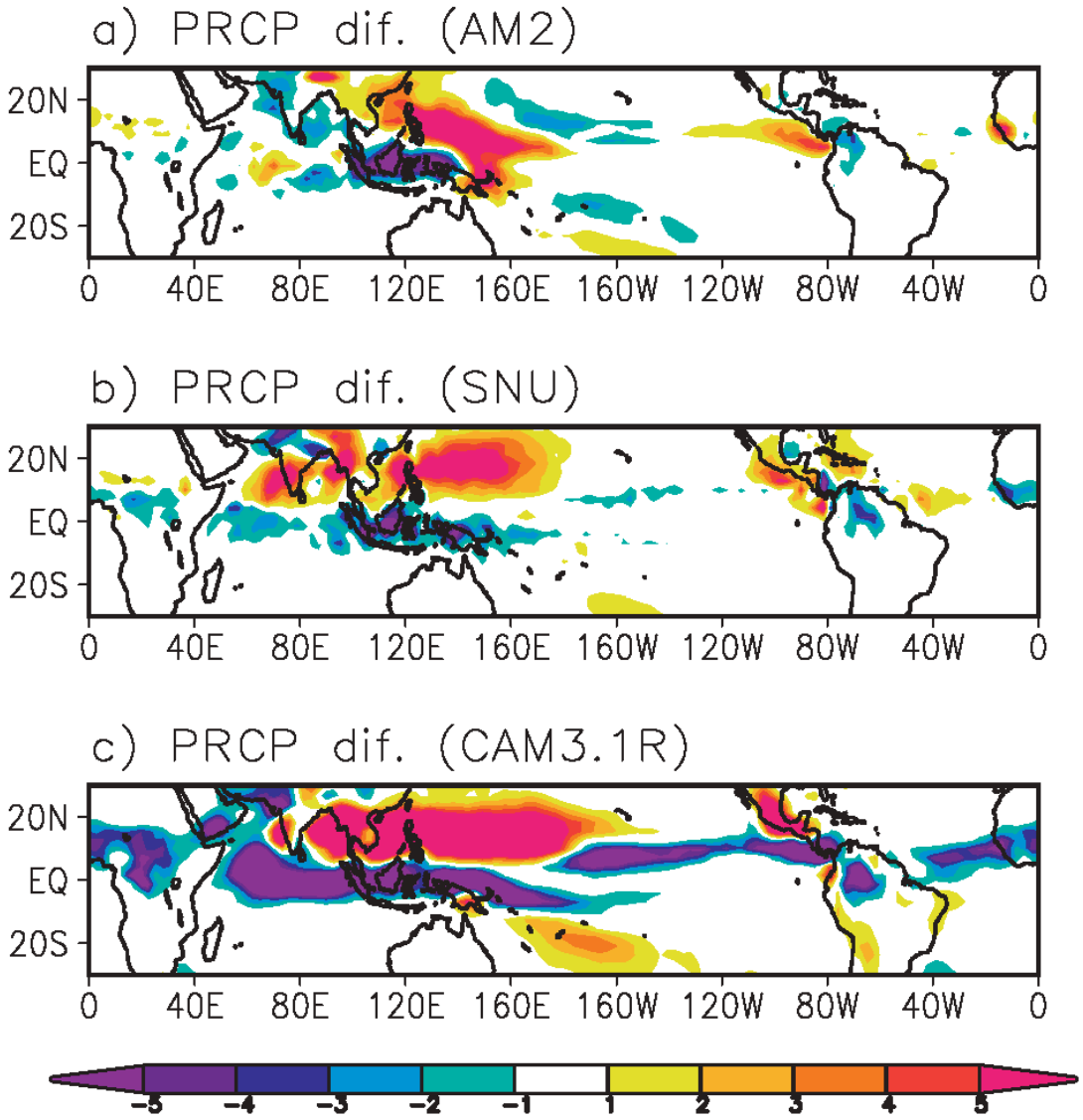
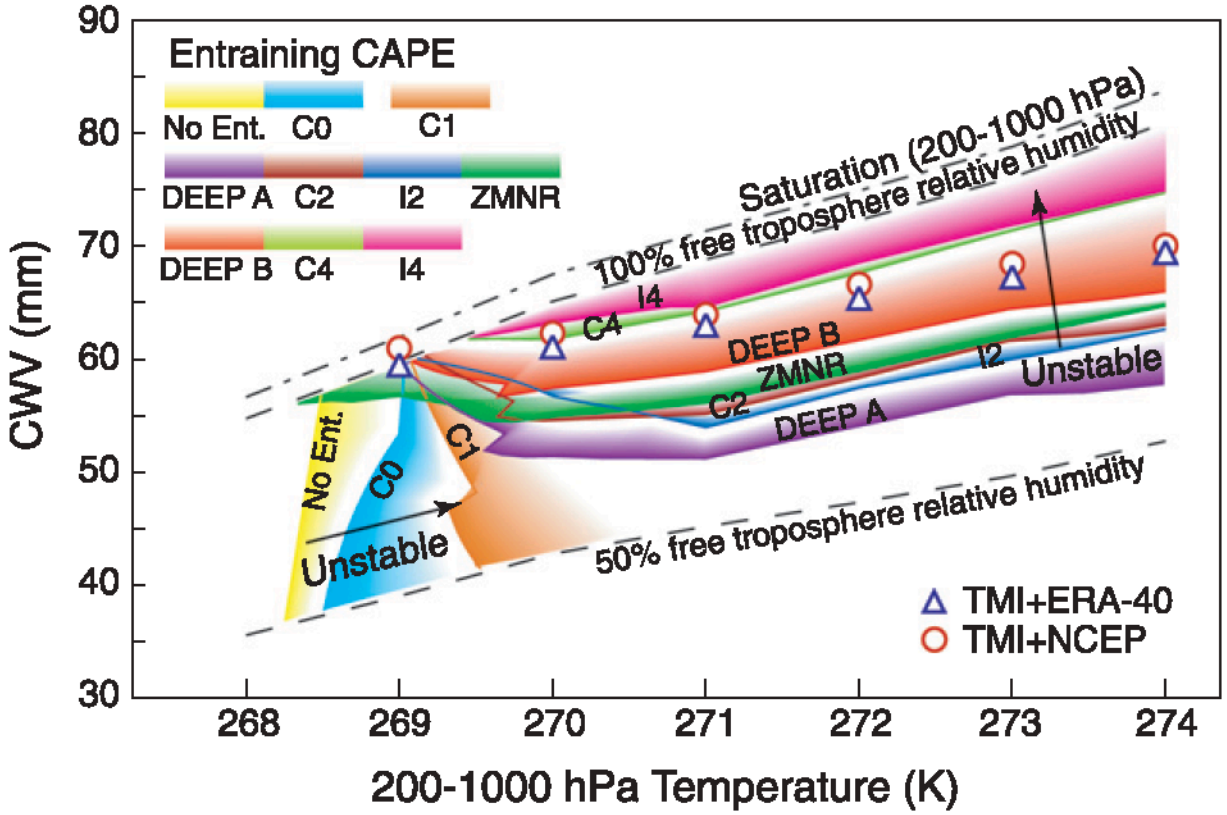


Link to Mean State Bias in Models with Strong MJO?

Strong horizontal advection associated with overactive rotational disturbances and common mean state biases characterizes many models with strong MJOs

Kim et al. (2011)

Convective Onset Diagnostics for Different Entrainment Profiles



Convective onset column water vapor content as a function of temperature and treatment of entrainment

Sahany et al. (2012)

Modeling Center Discussions (NCAR, GFDL)

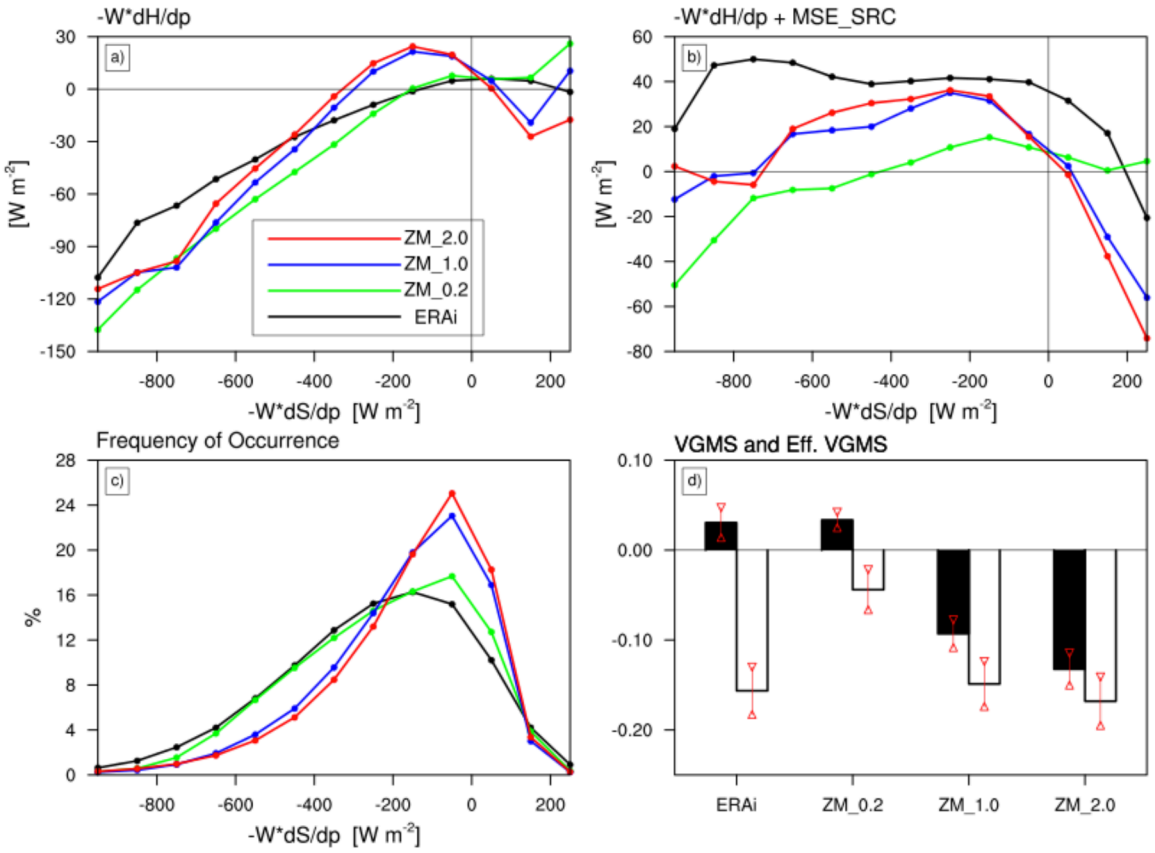
- Interest in expanding process-oriented diagnosis of models
- Need to focus efforts on incorporating process-oriented diagnostics to developmental model versions of ESMs (i.e. feed back more rapidly onto model improvement and bias reduction than a CMIP cycle)
- Incorporating diagnostic analysis into standard community diagnostic packages used by modeling centers, so diagnostics can be rapidly repeated across model versions
- Leverage and extend the utility of existing efforts (CPTs and task forces) and maximize their effectiveness.

Conclusions

- I provided an introduction to limited examples process-oriented model diagnostics being developed to provide insight into model behavior.
- Pilot project with NCAR called Climate Analysis Projects (CAP) to implement these diagnostics into development stream of NCAR CAM.
- Have also been discussing joint efforts with other modeling centers (e.g. GFDL) and the applications community about this diagnostic framework and possible collaborations.
- NOAA MAPP CMIP5 Task Force actively developing diagnostics for N. American climate (as MJOTF is for MJO) ex: blocking, TCs, Great Plains precip, etc.


Thanks

Calculation of GMS



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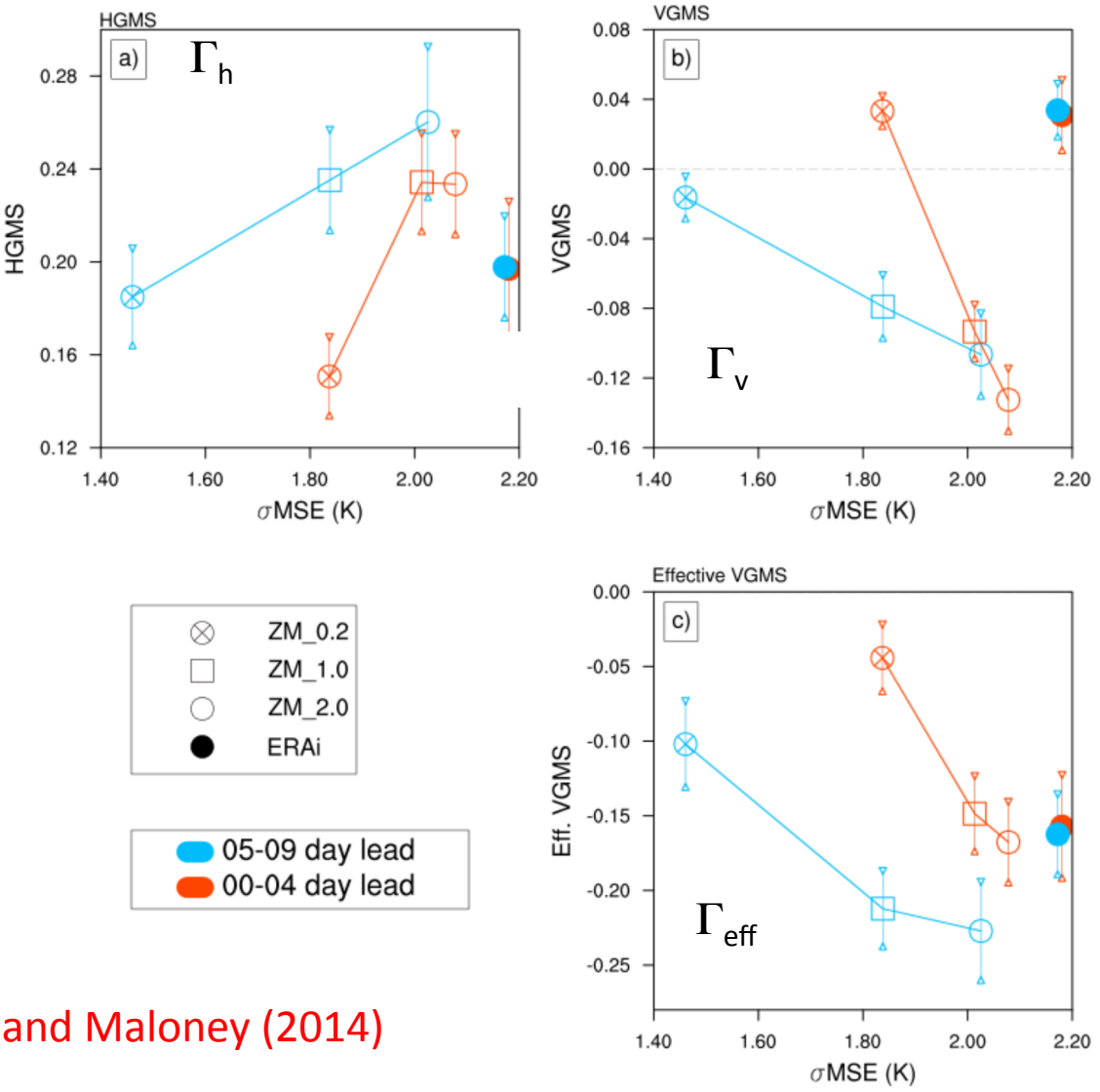

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